FAR IR AND SUBMILLIMETER FILLED BOLOMETER ARRAYS PERFORMANCES AT 300 mK AND 2K

Vincent Reveret, Louis Rodriguez*, Laurent Vigroux
CEA/DSM/DAPNIA Service d'Astrophysique, CEA Saclay, 91191 Gif sur Yvette Cedex, France

Patrick Agnese
LETI/CEA Grenoble, 17 avenue des Martyrs, 38054 Grenoble Cedex 9, France

ABSTRACT

CEA developed large (2048 pixels) filled bolometer arrays for the HERSCHEL PACS photometer in the 60-200 µm spectral band. We present the detector design and its performances at 300 mK. The PACS spectral band can easily be extended to longer wavelengths for future applications. Some details of the possible adaptation are given here. We also evaluate the expected performances when adapted and operated at higher temperature (2K). Calculations show that, in this condition, the expected NEP is close to 1.10^{-15} W/Hz$^{1/2}$ for a 100 pW/pixel flux.

INTRODUCTION

HERSCHEL, the future far infrared and submillimeter observatory, will include three instruments. Two of them, PACS[1] and SPIRE[2], are spectro-photometers and are designed for observations between 60 and 200 µm, and 200 and 600 µm respectively. CEA/LETI/DOPT/Laboratoire Infrarouge and CEA/DSM/DAPNIA/Service d'Astrophysique are developing new technology bolometer arrays optimized for the PACS photometer. The design was motivated by the need to provide very good image quality and fast mapping speed in high background conditions. These requirements have led to the following constraints:

- Optimal sampling of the PSF (0.5 Fλ pixel field of view)
- Large number of pixels (> 1000) to get large field of view
- Use of existing technologies to minimize development time and ensure a good production yield
- Integrated cold electronics including cold multiplexer
- Low operating temperature (300 mK) easily achievable by sorption coolers

The need for a manufacture based on existing technology has led to an all silicon design:

- Ionic implantation to obtain resistive thermometers
- Silicon micro-etching to realize suspended absorbing grids
- Flip-chip technology to assemble the different functions
- CMOS cold multiplexer and readout electronics

PACS photometer is divided in two bands :

- 60-130µm devoted to the "blue" focal plane (32 x 64 pixels),
- 130-210 µm measured by the "red" focal plane 16 x32 pixels).

The first PACS focal plane was completed in January 2002.

* *Contact information for L. Rodriguez - Email : louisrod@cea.fr*

DETECTOR DESIGN

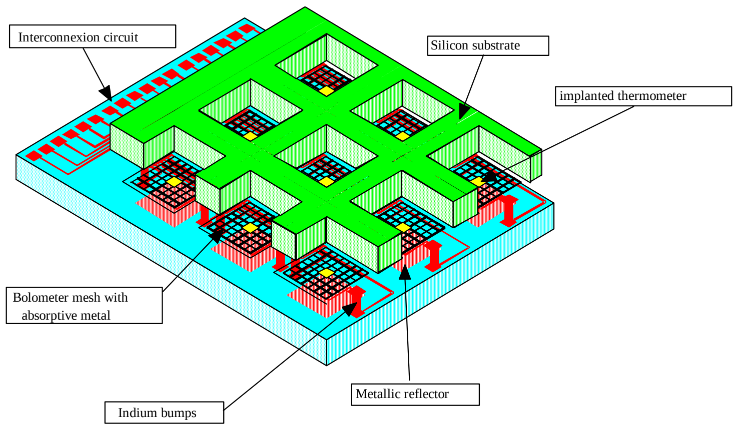

Figure 1:*conceptual drawing of the Bolometer array developed for Herschel PACS.*

Thermometer

The choice of CMOS cold electronics requires very high responsivity bolometers (10^{10}V/W or more). Such value is obtained by increasing the thermometers impedance to reach 1 to 10 GΩ. During the early phases of this project, we have demonstrated that it was possible to achieve such high resistance thermometers at 300mK in the hopping conduction regime with phosphorus implantation and 50% Boron compensation. To ensure a good homogeneity of the implantation, we have developed a new process by ion implantation on a double silicon-on-insulator (SOI) substrate. The thermometer is implanted on the silicon, above the oxide; then the implantation is homogenized by thermal diffusion. Contact pads are implanted above the thermometer and micro-etching of the thermometric layer produces the thermometer at the required geometry.

Grids and metallic absorption layer

The absorption principle is based on resonant absorption by a metallic layer placed above a quarter wave resonant cavity. The high absorption efficiency profile can be extended beyond the vertical resonant cavity peak by suitable grid patterns, which create an “horizontal” resonance. The cavity is obtained, in our design, by two silicon layers. On the upper one, we have the suspended silicon grids with absorbing metal, beneath a gold reflector is deposited on the second silicon substrate, also used for the cold readout electronics. Indium bumps in between ensure the mechanical support of the grid layer and tune the cavity size. 20 and 25 µm bumps are used respectively for the blue and the red channels of PACS. The indium bumps also permit the electric contact with the thermometers, and ensure the thermal link of the bolometers with the 300 mK cryocooler tip.

Thermal design

The thermal decoupling between the absorbing grid and the silicon substrate is ensured by thin rods of silicon. The thermal impedance of these rods is $\sim 10^{11}$ K/W at 0.3 K for rods of 1mm length and 2 µm x 5 µm section. The passivation layer is silicon oxide, preferred to the "heavy" silicon nitride used previously. At 0.3 K the bulk silicon dominates the thermal impedance.

Signal processing

MOS transistors are implanted directly below each pixel and adapt the high impedance of the bolometers to the following amplifying stage at 2K. The possibility to commute between a reference voltage source and the bridge signal above the MOS readout allows double correlated sampling to remove the 1/f noise component of the MOS follower. This stage and the 16 to 1 multiplexer are implanted in the silicon plate below the absorbing grids. They are all working at 300 mK. A second stage of amplification is provided by

another PMOS preamplifier at 2 K. Two lines of blind pixels are implanted on the side of the 16x16 active pixel arrays. They are used to determine all the collective perturbations that affect the signal via differential measurements.
The following figure shows one of the assembled blue focal plane.

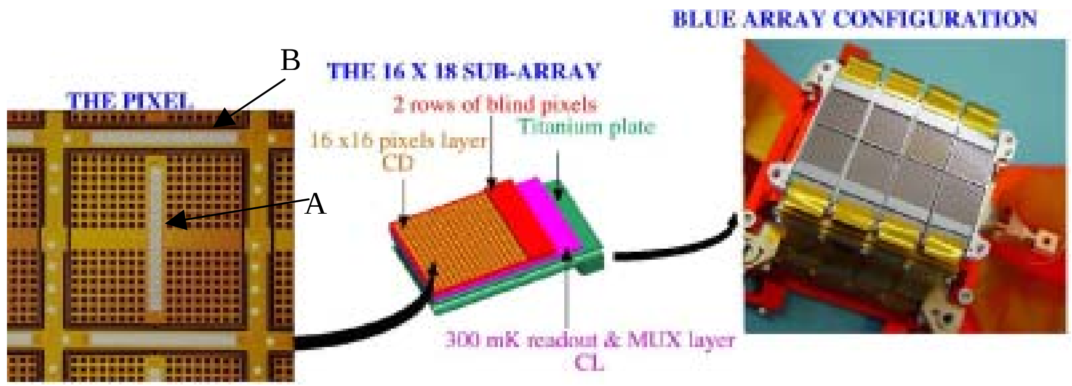

__Figure 2:__From left to right: a close view of the pixel grid (with the bolometric thermometer A in the center, and two reference thermometers B), a schematic drawing of the detector structure, and the complete blue focal plane with 8 sub-arrays.

RESULTS

Tests at 300 mK

The bolometer arrays have been successfully tested[3] for vibration and shocks at 77 K.
The power budget available for bolometer operations is 14 µW, which is compatible with the thermal dissipation of the 300 mK MOS followers.
All the operating modes of the control and readout electronics, multiplexer, double correlated sampling, differential mode with the blind pixels, have been tested and are functional.
We measured the noise spectral density to be 1µV/ Hz at 10Hz in the 40 Hz multiplexed mode. The infrared load per pixel was ~1 pW, simulating the optical load inside the PACS instrument. In these conditions, we measured a response of $\sim 10^{10}$ V/W, using an internal 20 K black body and a temperature controlled cold chopper, leading to an NEP of 10^{-16} W/ Hz which corresponds to the BLIP conditions.
The spectral response of the bolometers has been measured in a polarizing Fourier Transform Spectrometer. Early results show more than 85% of absorption in the two PACS bands. Uncertainty in the results is quite important for the highest frequencies because of problems with polarizing grids.

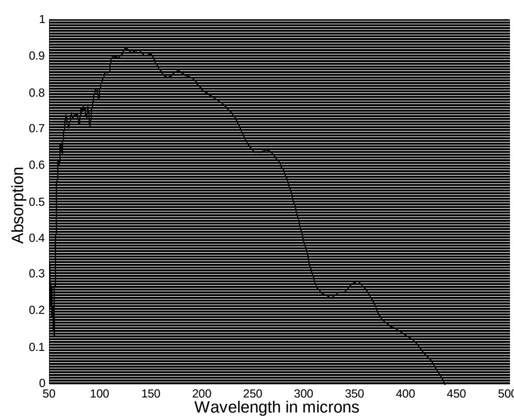

***Figure** 3:Absorption curves for the "Red" (--) array and "Blue" (-) array.*

We are currently working on a system to increase the absorption in longer wavelengths (up to the 870 µm atmospheric band). The system will be made of simple dielectric materials deposited on the top of the bolometer and will act as an anti-reflecting layer (2002 CEA patent).

Simulations for the 2K case

The estimation of the performances at 2K is based on a numerical model that solves the bolometer differential equation with the specific parameters of the CEA bolometers. The optimum bias is estimated and leads to a total NEP of 10^{-15} W/ Hz at 200 µm, for a 100 pW per pixel flux. This value is dominated by the MOS noise. The phonic noise is of the same order of magnitude as the photonic noise (~ 7.10^{-16} W/ Hz).

CONCLUSION AND PROSPECTS

The results so far demonstrate the validity of the technical choices behind the design of these bolometer arrays. The noise performances and the optical absorption are good enough to achieve BLIP conditions in HERSCHEL PACS.

A simple solution has been found to adapt these bolometers to the detection of longer wavelengths (100 µm to 850 µm). In a near future, we envisage to develop other arrays at 450 and 865 µm for ground based or balloon instruments. In particular a balloon instrument, ELISA, is under evaluation by CNES, to be launched in 2005 – 2006 (PI:I. Ristorcelli, CESR, France).

REFERENCES

1. A. Potglitsch, C. Waelkens, N. Geis, *The Photodetector Array Camera and Spectrometer (PACS) for Herschel*: Proc. The Promise of the Herschel Space Observatory, 12-15 December 2000, Toledo, Spain, G.L. Pilbratt, J. Cernicharo, A.M. Heras, T. Prusti, R.A. Harris Edts. ESA publications, SP-460, page 29
2. M.J. Griffin, B.M. Swinyard, L. Vigroux: *The SPIRE instrument for Herschel,* Proc. The Promise of the Herschel Space Observatory, 12-15 December 2000, Toledo, Spain, G.L. Pilbratt, J. Cernicharo, A.M. Heras, T. Prusti, R.A. Harris Edts. ESA publications, SP-460, page 37
3. L. Rodriguez et al, Proc SPIE 4855, 108, 2003